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**TEST RESULTS OF PHASE 3 LEVEL B SUITS
TO CHALLENGE BY CHEMICAL AND
BIOLOGICAL WARFARE AGENTS AND SIMULANTS:
SUMMARY REPORT**

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EXECUTIVE SUMMARY

As part of the Domestic Preparedness Program, three Occupational Safety and Health Administration Level B* suit designs were tested to assess their capability to protect in a chemical warfare (CW) agent or biological agent environment. Swatches of material from each suit design were tested for resistance to permeation by Sarin (GB) and mustard (HD). From these data, the authors calculated the estimated time it would take to permeate the suit with sufficient agent to cause physiological effects in a person wearing the suit. Each suit design was also tested for its protection factor in an aerosol environment (aerosolized corn oil, which may be representative of a chemical or biological agent, was used). Protection factor is defined as the ratio between the challenge concentration outside the suit and the measured concentration inside the suit. The tests are described, and the calculated physiologically-derived breakthrough times and protection factors (PF) are presented.

* Level B protection consists of chemical-resistant clothing (overalls and long-sleeved jacket; hooded one or two piece chemical splash suit; disposable chemical-resistant one-piece suit), inner and outer gloves, chemical-resistant safety boots and hardhat with pressure-demand full-facepiece SCBA or pressure-demand supplied-air respirator with escape SCBA. Level B, rather than Level A, protection is used when a high level of respiratory protection is required but less skin protection is needed.

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PREFACE

The work described in this report was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Edgewood Chemical Biological Center (ECBC) Homeland Defense Business Unit. This work was started in April 2000 and completed in September 2000.

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TEST RESULTS OF PHASE 3 LEVEL B SUITS TO CHALLENGE BY CHEMICAL AND BIOLOGICAL WARFARE AGENTS AND SIMULANTS: SUMMARY REPORT

1. INTRODUCTION

In 1996, Congress passed Public Law 104-201 (Defense Against Weapons of Mass Destruction Act of 1996), directing the Department of Defense (DoD) to assist other federal, state, and local agencies in enhancing preparedness for terrorist attacks using weapons of mass destruction. The DoD responded by forming the Domestic Preparedness Program that same year. One of the objectives of the Domestic Preparedness Program is to enhance emergency and hazardous material response to nuclear, biological and chemical (NBC) terrorism incidents. As part of an effective response, people who are responding to an incident will use personal protective equipment to protect them from exposure to chemical agents or biological agents. The specific personal protective equipment (PPE) that will be used depends upon the situation that they encounter and what they have on hand. In some cases, Level B protective suits may be required to enter a contaminated or potentially contaminated area. Level B suits are chemical-resistant clothing that protect the wearer from liquid chemicals. Air is supplied by a pressure-demand full-facepiece self-contained breathing apparatus (SCBA) or pressure-demand supplied-air respirator with escape SCBA.

2. OBJECTIVES

This study evaluated three different common and commercially available Level B suits. These three different suits met the Occupational Safety and Health Administration (OSHA) description of Level B as defined in 29 Code of Federal Regulations (CFR) 1910.120, Appendix B. These suits were evaluated to assess how well they resist vapor permeation¹ from liquid contamination by chemical agents Sarin (GB) and mustard (HD) and droplet penetration by a corn-oil aerosol from 0.4 to 0.6 microns in diameter (used to simulate the 0.4 to 5 micron military standard for the possible biological or chemical particulate threat). This information is intended for emergency responders as an aid in evaluating Level B suits when they choose to include military chemical and biological agent protection as a criterion. The information supplements data and information provided by the suits' manufacturers. The suits are tested in new, as-received condition. The effects of aging, temperature extremes, laundering, and other factors are beyond the intended scope of this test program. These tests are conducted to assess percutaneous protection² only.

3. TESTING AND DATA ANALYSIS

3.1 Testing Overview.

The Level B suits that were tested in this test program are listed in Table 1.

¹ Throughout this report the term permeation is used even though for some of the tests the precise mechanism of agent transfer is not determined and penetration is likely to be involved also.

² Inhalation and ocular protection are typically provided by the use of a SCBA or air-supplied respirator that covers the eyes, nose and mouth.

Table 1. Level B Suits Tested

| Model | Manufacturer | Address |
|--------------------------------|-----------------------------|----------------|
| Lakeland Coverall, Style 94165 | Lakeland Industries, Inc. | Somerville, AL |
| Mar Mac Coverall, Model 94124 | Mar Mac Manufacturing, Inc. | McBee, SC |
| Mar Mac Coverall, Model 100124 | Mar Mac Manufacturing, Inc. | McBee, SC |

Tests included the measurement of permeation of both GB and HD through material swatches. Tests were also conducted to measure the total aerosol leakage into the suits through seams, seals, etc., when worn as part of a complete PPE system.

3.2 Liquid Challenge/Vapor Permeation Testing (Agent Swatch Testing).

3.2.1 Liquid Challenge/Vapor Permeation Testing Procedures.

This testing was conducted to measure the actual permeation of chemical agents GB and HD through suit swatches over a 24-hour period. The test was intended to assess how well the suit materials and seams resist agent permeation. For each suit design, all swatches were taken from a single suit. The amount of agent applied and duration of exposure do not represent any particular threat that responders may encounter, but they do serve as a common point of reference for all test results.

The test methodology was taken from TOP 8-2-501³ and is described in Appendix A. Three swatches were taken from each of six different areas of the suit – 18 total swatches per suit design for GB and 18 more for HD. Swatches were taken from silicone rubber (M45 mask formulation) slabs⁴. For each test six swatches taken from a suit and one silicone swatch were placed in test cells, one swatch per test cell. Laboratory personnel applied a predetermined liquid agent challenge (10 g/m²) to the top surface of each swatch. Agent droplets were applied to the surface of the first swatch at time zero. Agent was then applied to the surface of each succeeding swatch at 3-minute intervals. The upper chamber of each test cell was sealed. A 1.0 L/min flow of air, from the test cabinet, was maintained in the lower test cell chamber beneath each swatch.

During the 24-hour test period, gas samples were taken on a sequential basis by a laboratory MINICAMS™ (OI Analytical, CMS Field Products Group, Birmingham, AL) with stream selection system (a miniaturized gas chromatograph with flame photometric detector and sampling system) from the air stream beneath each swatch. Gas sampling by the MINICAMS™ began for the first swatch approximately 3 minutes following agent application. Subsequent 3-minute cycles of the MINICAMS™ were composed of 2 minutes of desorption of collected agent vapor from the pre-concentrator tube (PCT) onto the GC column followed by 1 minute of gas sampling (collection of agent vapor in the PCT). Sampling was done sequentially through six

³ Test Operations Procedure (TOP) 8-2-501, Permeation and Penetration of Air-Permeable, Semipermeable and Impermeable Materials with Chemical Agents or Simulants (Swatch Testing). U.S. Army Dugway Proving Ground, UT 3 March 1997, UNCLASSIFIED Report (AD A322329).

⁴ Originally, it was intended to use silicone swatches as references or controls, but it was soon found that permeation through the silicone varies too widely for it to be used for that purpose. Silicone swatches were used anyway, because they serve as a reliable source of agent vapor to assure the tester that the MINICAMS™ is responding properly during tests when little or no agent permeates the actual test swatches.

swatches (three from one sampling area followed by three from a second sampling area), the silicone swatch, and then three blank gas samples were taken from the test chamber to purge the sampling line before repeating the sampling sequence. The six swatches, the indicator swatch, and three blanks were all sampled for the first time within the first 30 minutes of the test. Then the sampling sequence began anew.

The MINICAMS™ first determined the amount of agent vapor in each gas sample. Using this result, the amount (ng) of agent vapor present in the air stream that passed beneath the swatch over the time from one gas sample to the next was determined by the MINICAMS™ permeation software. This amount of agent vapor is presumed to be the amount of agent vapor that has permeated the swatch over that time interval. Given the area of the test swatch, the MINICAMS™ permeation software determines the M_f at each elapsed time for each swatch, where the cumulative mass of agent permeating the swatch per unit area at any elapsed time during the 24-hour test is defined as M_f .

3.2.2 Liquid Challenge/Vapor Permeation Testing Analysis.

Each suit yielded M_f data for 18 swatches for each of the two agents over the 24-hour test period. The M_f data are taken for each of the three swatches from one sampling area tested with one of the agents. For this report, the average (of three swatches) cumulative permeation (M_f) for each suit area (for example, gloves) is calculated. This average is then presented, at each of the reported elapsed times, as representative of the suit's permeation resistance at that sampling area. The reported elapsed time for each sampling area is the sum of the elapsed times for the three swatches divided by three. For each suit tested, swatches were taken from a single suit.

To estimate M_f at each elapsed time for a suit, the simplifying assumption is that the exposure is uniform over the entire suit. This permits the use of the weighting factor scheme developed by Belmonte⁵ to determine the weighted average M_f over the entire suit at each average elapsed time. The average elapsed time is the sum of the reported elapsed times for all the sampling areas divided by the number of sampling areas. The weighting factors shown in Table 2 were assigned roughly on the basis of surface area assigning a minimum assigned value of 5%. Swatches were not necessarily taken from exactly the same locations for all suits because the suit configurations differed. Note that not all suits have the same components. The weighted average M_f at any average elapsed time is calculated using an equation similar to the following (using the Lakeland 94165 suit weighting factors in Table 2 for this example):

$$\text{Weighted average } M_f = 0.3(\text{suit chest material } M_f) + 0.3(\text{suit leg material } M_f) + 0.15(\text{suit arm seam } M_f) + 0.15(\text{hood seam } M_f) + 0.05(\text{boot seam } M_f) + 0.05(\text{zipper seam } M_f)$$

⁵ Belmonte, R.B., *Test Results of Level A Suits to Challenge by Chemical and Biological Warfare Agents and Simulants: Summary Report*, ERDEC-TR-513, U.S. Army Edgewood Research, Development and Engineering Center, Aberdeen Proving Ground, MD, August 1998, UNCLASSIFIED Report (AD A353013).

Table 2. Weighting Factors For Each Sampling Area by Suit

| Suit Model | Suit Chest Material | Suit Leg Material | Suit Arm Seam | Crotch Area | Boot Seam | Hood Seam | Hood Material | Zipper Seam |
|--------------------------------|---------------------|-------------------|---------------|-------------|-----------|-----------|---------------|-------------|
| Lakeland Coverall, Style 94165 | 30 | 30 | 15 | - | 5 | 15 | - | 5 |
| Mar Mac Coverall, Model 94124 | - | 50 | 15 | 15 | 5 | - | 10 | 5 |
| Mar Mac Coverall, Model 100124 | - | 50 | 15 | 10 | 5 | - | 15 | 5 |

3.2.3 Relationship Between Liquid Challenge/Vapor Permeation Test Results and Skin Exposure.

The permeation test is designed to distinguish among these material swatches according to their permeation resistance to chemical agents. It is not intended to specifically replicate threat scenarios that may be encountered in actual use. As previously reported by Belmonte⁵, it is instructive to estimate the agent dosage ($C_{it_{skin}}$) that would result from such a standard agent challenge as a relative indication of possible physiological effects. This is done by converting the weighted average M_s to equivalent agent dosages. This relationship was developed by Fedele (written communication, Dr. P. Fedele, R&T Directorate, ERDEC, July 1997) and was reported by Belmonte⁵. For suit materials impermeable to airflow, the equation is:

$$\text{Agent Dosage (mg - min/m}^3\text{)} = \frac{M_f \text{ (ng/cm}^2\text{)}}{P_s, \text{ Permeability of skin to agent vapor (cm/min)}}$$

where skin permeability (P_s) is 2 cm/min for HD and 0.1 cm/min for GB. The agent dosage can then be compared to doses that are known to cause certain levels of toxicity. Skin permeability is assumed to be constant over all regions of the body.

3.2.4 Evaluation Criteria for Liquid Challenge/Vapor Permeation Test Results.

When analyzing the test results, it is useful to determine whether the data indicate that the Level B suit provided percutaneous (i.e., skin) protection over some period of time. Mustard vapor can produce erythema (reddening of the skin, certain body regions) at dosages of approximately 100 mg-min/m³, and can produce vesication (skin burns and blisters, certain body regions) at 200 mg-min/m³. Sarin vapor can produce incapacitation (twitching, convulsions or loss of consciousness) at unprotected, percutaneous dosages of approximately 8000 mg-min/m³ and can be lethal at unprotected, percutaneous dosages of 15000 mg-min/m³ where exposed persons are healthy, young, fit, and well-nourished males of approximately 70-kg mass. People,

who are smaller, less fit, etc., may exhibit adverse effects at lower doses ($C_{i,skin}$). The conservative simplifying assumptions were that the suit would be exposed to a uniform liquid GB challenge over its entire surface, and that this would result in a uniform exposure of all body regions to GB vapor. This is conservative because the areas likely to receive more exposure (hands, arms, chest, back) would also be those less sensitive. Therefore, the amount of agent per unit area (weighted average M_f) necessary to permeate the suit to produce a predetermined physiological effect was estimated by using each of the above dosages and the appropriate skin permeability (P_s). These values are used in the graphs of weighted average M_f versus time given in Appendixes C through F and summarized in Table 3. The breakthrough dosages are assumed to be the HD dosage that produces erythema (100 mg-min/m^3) and the GB dosage that produces incapacitation (8000 mg-min/m^3). A physiologically-derived breakthrough time is the time when the weighted average M_f equals the breakthrough M_f criterion.

Table 3. Agent Breakthrough Criteria

| Agent | Breakthrough Dosage (mg-min/m^3) ^a | Physiological Effect | Skin Permeability (P_s), (cm/min) | Breakthrough M_f , (ng/cm^2) ^a |
|-------|--|----------------------|---------------------------------------|--|
| HD | 100 | Erythema | 2 | 200 |
| HD | 200 | Vesication | 2 | 400 |
| GB | 8000 | Incapacitation | 0.1 | 800 |
| GB | 15000 | Lethality | 0.1 | 1500 |

^a These breakthrough criteria are not to be construed as safe threshold values; they are being used only to rank suits.

3.3 System Test (Aerosol Simulant).

3.3.1 Aerosol Simulant Test Procedures.

The testing was conducted to determine leakage of a challenge corn-oil aerosol (physical simulant of a biological or chemical agent aerosol) into a suit ensemble while people of different sizes are wearing appropriately sized ensembles. Volunteers dressed in Level B suits with SCBA entered a chamber with aerosol simulant and performed a standardized series of exercises. Instrumentation measured any aerosol leakage (presumed to be penetration) into the suit through gaps between ensemble components. During the test, the people in the suits performed standardized movements. A brief description of the test and movements made by the people during the test are given in Appendix B. Three different ensembles, listed in Table 1, were tested. Eight suits of each design were worn by 12 volunteers on each of two days, for a total of 24 trials for each suit design. However, because it was not possible to retain the same 12 volunteers throughout the entire course of testing, this variable (the differences among wearers) was not held constant across all suit designs.

From this test a protection factor (PF) was derived. In simplest terms, PF is a measure of the challenge concentration outside the suit divided by the concentration inside the suit ensemble. For example, if the concentration of aerosol inside the suit ensemble is found to be 1/10th the value of the average concentration outside the suit ensemble, the PF is equal to 10.

3.3.2 Aerosol Simulant Analysis.

Samples of aerosol were taken continuously at the neck area and upper arm within the suit and their concentrations were measured by laser photometry, recorded in a computer file and displayed continuously on a computer monitor. These sampling locations were selected as being the most likely locations for aerosol leakage to occur (Leakage usually occurs near openings such as the neck, visor, zipper or outlet valve openings). This is thought to be the worst case and the PF is a worst case PF.

The PF data are presented based upon predetermined PF pass levels, ranging from 2 to 100,000 (i.e., at each pass level the number of failing and passing suits is recorded). The higher the percentage of test occasions that passes at a given PF, the greater the probability that the suit will provide that level of protection in use.

ACRONYMS and ABBREVIATIONS

| | |
|-----------------------|--|
| CFR | Code of Federal Regulations |
| Ct | Vapor exposure, product of vapor concentration (mg/m^3) and time (minutes) |
| $C_{t_{\text{skin}}}$ | Vapor exposure to skin |
| cm^2 | Square centimeters |
| $^{\circ}\text{F}$ | Temperature in degrees Fahrenheit |
| delta p | Differential pressure |
| DoD | Department of Defense |
| ECBC | U.S. Army Edgewood Chemical Biological Center |
| ERDEC | U.S. Army Edgewood Research, Development and Engineering Center |
| g | Gram |
| GB | Sarin, Isopropylmethylphosphonofluoridate |
| GC | Gas chromatograph |
| HD | Sulfur Mustard; 2,2'-Dichlorodiethylsulfide |
| kg | Kilograms |
| L | Liter |
| M_f | Cumulative mass permeation through the fabric |
| m^2 | Square meters |
| m^3 | Cubic meters |
| mg | Milligram |
| μL | Microliter |
| ng | Nanogram |
| NBC | Nuclear, Biological and Chemical |
| OSHA | Occupational Safety and Health Administration |
| PCT | Pre-concentrator tube |
| PF | Protection Factor |
| PPE | Personal Protective Equipment |
| P_s | Skin permeability |
| RH | Relative Humidity |
| SCBA | Self-Contained Breathing Apparatus |
| TOP | Test Operations Procedure |

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Appendix A

Modified Static Diffusion Test Procedure

MODIFIED STATIC DIFFUSION TEST

This test procedure was adapted from Test Operations Procedure (TOP) 8-2-501, Permeation and Penetration of Air-Permeable, Semipermeable and Impermeable Materials with Chemical Agents or Simulants (Swatch Testing), U.S. Army Dugway Proving Ground, UT, 3 March 1997, UNCLASSIFIED Report (AD A322329). The test procedure was entitled "Semipermeable and Impermeable Materials Static Diffusion Penetration Testing (Liquid Agent Challenge/Vapor Penetration; $\Delta p = 0$, Single Flow Test)". The following procedure was used:

1. Upon receipt of a suit, all available information concerning the suit will be recorded; date of manufacture, lot number, serial number, materials of construction, etc.
2. From each suit, three each 1 and 15/16-in diameter material swatches will be taken for mustard (HD) and a like number taken for Sarin (GB). Depending upon the suit configuration, 3 seam swatches (same diameter) will be taken plus 3 swatches of other flat components such as visor, gloves, suit/visor interface and zipper/material interface for HD and an equal number for GB. Each swatch will be placed in an airtight bag and given a unique serial number, which will be placed on the bag. A list of serial numbers will be kept with the swatches. Alternatively, the swatches for each day's test will be cut from the suit and placed in the environmental chamber for conditioning. Sample identification will accompany each swatch.
3. The environmental chamber will be controlled at a temperature of 90 \pm 2 °F, and the maximum achievable relative humidity (RH) without occurrence of condensation (normally 50% \pm 10% RH). The temperature and RH readings will be checked weekly with a calibrated meter. The test cell air will be drawn from the chamber air. The TOP 8-2-501 specifies that a system control and data acquisition system will be used, but this system will not be used due to budget constraints. The temperature and RH will be recorded in a computer file. Flow rates will be manually recorded. The TOP 8-2-501 specifies that differential pressure monitoring will be done but differential pressure gages will not be used due to budget constraints.
4. The TOP test cell will be used. When assembling, the cell lugs will be tightened by hand to finger tight. The flow rate beneath each swatch will be 1 L/min, which will be controlled by a linear mass flow controller. The flows will be checked with a calibrated test meter weekly. Each test cell will be checked for leaks after assembly by connecting it to the vacuum source and checking that the inlet flow is the same as the outlet flow on the mass flow controller. If the flows don't match, the test cell will be disassembled, adjustments made, the test cell reassembled and flows rechecked.
5. The TOP 8-2-501 specifies that positive control and negative control swatches will be used, but they will not be used due to budgetary and schedule limitations. The swatches will be preconditioned for at least 2 hr and will be monitored by MINICAMS™ for at least one cycle prior to agent application. Eighty-mil silicone will be used, one for each test (six suit swatches and one silicone swatch).

6. Agents GB and HD will be used. The contamination density will be 10 g/m^2 (8 each $1 \text{ }\mu\text{L}$ HD droplets or 10 each $1 \text{ }\mu\text{L}$ GB droplets). A robotic agent application system is not available. The agent will be applied using the click/touch method with a repeating dispenser.

7. Seven swatches will be tested at once. MINICAMS™ with stream selection system will monitor vapor penetration with a 3-min cycle. There will be three sampling intervals following the silicone during which chamber air will be sampled. Each swatch will be sampled once every 30 min. The MINICAMS™ will be standardized weekly with a range of agent standards (diluted in isopropanol); concentrations will normally range from $1 \text{ ng}/\mu\text{L}$ to $100 \text{ ng}/\mu\text{L}$.

8. The test length will be 24 hr.

9. The test cells will be aerated and o-rings replaced between uses. No other cleaning method will be used.

10. The data to be reported are cumulative permeation (ng/cm^2) at various elapsed times (minutes) for each swatch. The elapsed time for each swatch is the time from agent contamination. All recorded data will be placed in laboratory notebooks and one technical report per suit will be drafted at the conclusion of this effort.

Appendix B

Aerosol Simulant Test Procedure

To properly test suits with statistical significance, eight suit ensembles of each model are provided to the Mask Fit Test Facility for examination. Each ensemble is new and inspected as received. The suit ensembles include relevant accessory equipment such as respirators that are worn with the suits, gloves, boots, and any other equipment that is necessary for chemical agent use. The suit ensembles are run on at least 10 different subjects with at least 22 trials. The eight suits are reused to achieve the 22 or more trials. Sampling of suits is done at the neck and upper arm for each trial.

Exercise routine for all suits is as follows:

Phase 1 (Pre-Operational):

- 1) standing still, normal breathing
- 2) bending forward and touching toes
- 3) jogging in place
- 4) raising arms above head and looking upward
- 5) bending knees and squatting
- 6) crawling on hands and knees
- 7) torso twists with hands folded on chest
- 8) standing still, normal breathing

Phase 2 (Operational):

- 1) climb step ladder
- 2) move 3 lb boxes from table to floor
- 3) rest
- 4) roll walls and ceiling
- 5) bag clothes
- 6) rest
- 7) loosen bolts
- 8) move 3 lb boxes from floor to table

The phase 1 (pre-operational) exercises are performed for one min each for a total of eight minutes. The phase 2 (operational) exercises are normally performed for four minutes each for a total of 32 minutes. Hence, the overall total exercise time for the two phases is normally 40 minutes. In this case, however, because of the high leakage rates of the suits, the phase 2 exercises were only performed for one minute each.

Blank

Appendix C

Lakeland Coverall, Style 94165



Figure C - 1. Lakeland Coverall, Style 94165 - Front View

Table C - 1. Lakeland Coverall - Average HD Permeation

| Average Cumulative Permeation (ng/cm ²) | | | | | | | | | | | | | |
|---|-------------------|------------|---------------|------------|-----------|------------|---------------------|------------|-----------|------------|-------------|--------------------|---------------------------------|
| Time (min) | Suit Leg Material | Time (min) | Suit Arm Seam | Time (min) | Hood Seam | Time (min) | Suit Chest Material | Time (min) | Boot Seam | Time (min) | Zipper Seam | Average Time (min) | Weighted Average M _r |
| 5 | 1 | 12 | 1 | 14 | 3 | 4 | 3 | 14 | 1 | 4 | 0 | 9 | 2 |
| 35 | 33 | 42 | 7 | 44 | 18 | 35 | 36 | 44 | 12 | 33 | 22 | 39 | 26 |
| 65 | 65 | 72 | 15 | 74 | 30 | 65 | 58 | 74 | 25 | 63 | 81 | 69 | 49 |
| 95 | 70 | 102 | 25 | 105 | 39 | 96 | 83 | 104 | 29 | 93 | 177 | 99 | 66 |
| 125 | 77 | 132 | 37 | 135 | 48 | 126 | 109 | 134 | 34 | 123 | 301 | 129 | 85 |
| 155 | 85 | 162 | 51 | 165 | 57 | 156 | 137 | 164 | 40 | 153 | 451 | 159 | 107 |
| 185 | 93 | 192 | 68 | 196 | 67 | 187 | 167 | 194 | 46 | 183 | 619 | 189 | 132 |
| 215 | 105 | 222 | 87 | 226 | 78 | 217 | 200 | 224 | 54 | 213 | 801 | 220 | 159 |
| 245 | 118 | 252 | 108 | 256 | 89 | 247 | 237 | 254 | 63 | 243 | 996 | 250 | 189 |
| 275 | 133 | 282 | 131 | 287 | 102 | 278 | 280 | 284 | 73 | 273 | 1199 | 280 | 222 |
| 305 | 151 | 312 | 155 | 317 | 117 | 308 | 327 | 314 | 83 | 303 | 1404 | 310 | 259 |
| 335 | 171 | 342 | 181 | 347 | 136 | 338 | 378 | 344 | 95 | 333 | 1606 | 340 | 297 |
| 365 | 192 | 372 | 209 | 378 | 159 | 369 | 434 | 374 | 106 | 363 | 1805 | 370 | 338 |
| 395 | 215 | 402 | 236 | 408 | 187 | 399 | 493 | 404 | 118 | 393 | 1998 | 400 | 381 |
| 425 | 238 | 432 | 262 | 438 | 219 | 429 | 554 | 434 | 130 | 423 | 2186 | 430 | 425 |
| 455 | 261 | 462 | 289 | 469 | 258 | 460 | 616 | 464 | 142 | 453 | 2376 | 460 | 471 |
| 485 | 285 | 492 | 316 | 499 | 305 | 490 | 681 | 494 | 155 | 483 | 2561 | 491 | 519 |
| 515 | 308 | 522 | 342 | 529 | 359 | 520 | 746 | 524 | 168 | 513 | 2743 | 521 | 567 |
| 545 | 332 | 552 | 368 | 560 | 422 | 551 | 812 | 554 | 182 | 543 | 2922 | 551 | 617 |
| 575 | 357 | 582 | 393 | 590 | 494 | 581 | 879 | 584 | 195 | 573 | 3099 | 581 | 669 |
| 605 | 382 | 612 | 419 | 620 | 573 | 611 | 946 | 614 | 208 | 603 | 3277 | 611 | 721 |
| 635 | 406 | 642 | 445 | 651 | 658 | 642 | 1013 | 644 | 221 | 633 | 3454 | 641 | 775 |
| 665 | 431 | 672 | 470 | 681 | 747 | 672 | 1080 | 674 | 234 | 663 | 3628 | 671 | 829 |
| 695 | 455 | 702 | 495 | 711 | 843 | 702 | 1147 | 704 | 247 | 693 | 3800 | 701 | 883 |
| 725 | 478 | 732 | 520 | 742 | 944 | 733 | 1214 | 734 | 260 | 723 | 3971 | 731 | 939 |
| 755 | 502 | 762 | 545 | 772 | 1049 | 763 | 1283 | 764 | 272 | 753 | 4140 | 762 | 995 |
| 785 | 526 | 792 | 570 | 802 | 1158 | 793 | 1351 | 794 | 285 | 783 | 4308 | 792 | 1052 |
| 815 | 549 | 822 | 594 | 833 | 1275 | 824 | 1426 | 824 | 298 | 813 | 4474 | 822 | 1111 |
| 845 | 572 | 853 | 618 | 863 | 1400 | 854 | 1506 | 854 | 310 | 844 | 4638 | 852 | 1174 |
| 875 | 594 | 883 | 642 | 893 | 1531 | 884 | 1584 | 884 | 322 | 874 | 4802 | 882 | 1236 |
| 905 | 616 | 913 | 666 | 924 | 1666 | 915 | 1661 | 914 | 334 | 904 | 4966 | 912 | 1298 |
| 935 | 638 | 944 | 689 | 954 | 1804 | 945 | 1739 | 944 | 346 | 935 | 5129 | 943 | 1361 |
| 965 | 660 | 974 | 711 | 984 | 1945 | 975 | 1820 | 974 | 358 | 965 | 5290 | 973 | 1425 |
| 995 | 681 | 1004 | 733 | 1015 | 2088 | 1006 | 1905 | 1004 | 370 | 995 | 5451 | 1003 | 1490 |
| 1025 | 702 | 1035 | 755 | 1045 | 2234 | 1036 | 1994 | 1034 | 381 | 1026 | 5610 | 1033 | 1557 |
| 1055 | 722 | 1065 | 778 | 1075 | 2378 | 1066 | 2085 | 1064 | 393 | 1056 | 5768 | 1064 | 1624 |
| 1085 | 742 | 1095 | 800 | 1106 | 2517 | 1097 | 2179 | 1094 | 405 | 1086 | 5928 | 1094 | 1690 |
| 1115 | 760 | 1126 | 821 | 1136 | 2654 | 1127 | 2274 | 1124 | 416 | 1117 | 6086 | 1124 | 1757 |
| 1145 | 778 | 1156 | 842 | 1166 | 2789 | 1157 | 2370 | 1154 | 426 | 1147 | 6243 | 1154 | 1823 |
| 1175 | 796 | 1186 | 863 | 1197 | 2916 | 1188 | 2466 | 1184 | 437 | 1177 | 6400 | 1184 | 1887 |
| 1205 | 814 | 1217 | 884 | 1227 | 3037 | 1218 | 2560 | 1214 | 447 | 1208 | 6556 | 1215 | 1950 |
| 1235 | 830 | 1247 | 904 | 1257 | 3151 | 1248 | 2652 | 1244 | 457 | 1238 | 6708 | 1245 | 2011 |
| | | 1277 | 924 | 1288 | 3258 | 1279 | 2743 | | | 1268 | 6856 | | |
| | | 1308 | 943 | 1318 | 3360 | 1309 | 2832 | | | 1299 | 7000 | | |
| | | 1338 | 962 | 1348 | 3458 | 1339 | 2922 | | | 1329 | 7141 | | |
| | | 1368 | 981 | 1379 | 3551 | 1370 | 3012 | | | 1359 | 7282 | | |
| | | 1399 | 999 | 1409 | 3639 | 1400 | 3102 | | | 1390 | 7421 | | |
| | | 1429 | 1017 | | | 1430 | 3189 | | | 1420 | 7556 | | |

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_r = 0.3(\text{suit chest material } M_r) + 0.3(\text{suit leg material } M_r) + 0.15(\text{suit arm seam } M_r) + 0.15(\text{hood seam } M_r) + 0.05(\text{boot seam } M_r) + 0.05(\text{zipper seam } M_r)$

Table C - 2. Lakeland Coverall - Average GB Permeation

| Average Cumulative Permeation (ng/cm ²) | | | | | | | | | | | | | |
|---|-------------------|------------|---------------|------------|-----------|------------|---------------------|------------|-----------|------------|-------------|--------------------|---------------------------------|
| Time (min) | Suit Leg Material | Time (min) | Suit Arm Seam | Time (min) | Hood Seam | Time (min) | Suit Chest Material | Time (min) | Boot Seam | Time (min) | Zipper Seam | Average Time (min) | Weighted Average M _t |
| 13 | 0 | 5 | 0 | 4 | 1 | 12 | 1 | 4 | 0 | 14 | 0 | 9 | 1 |
| 43 | 8 | 35 | 964 | 33 | 10 | 42 | 13 | 34 | 4 | 44 | 1699 | 39 | 238 |
| 73 | 18 | 65 | 2871 | 63 | 27 | 72 | 27 | 64 | 11 | 74 | 5107 | 69 | 704 |
| 104 | 24 | 95 | 4666 | 93 | 47 | 102 | 35 | 95 | 16 | 104 | 8368 | 99 | 1144 |
| 134 | 27 | 125 | 6305 | 123 | 64 | 132 | 42 | 125 | 21 | 134 | 11314 | 129 | 1543 |
| 164 | 30 | 155 | 7773 | 153 | 78 | 162 | 49 | 155 | 24 | 164 | 13944 | 159 | 1900 |
| 195 | 32 | 185 | 9046 | 183 | 90 | 192 | 55 | 186 | 27 | 194 | 16249 | 189 | 2210 |
| 225 | 35 | 215 | 10142 | 213 | 102 | 222 | 60 | 216 | 32 | 224 | 18251 | 219 | 2479 |
| 255 | 40 | 245 | 11086 | 243 | 112 | 252 | 65 | 246 | 38 | 254 | 20001 | 250 | 2713 |
| 286 | 45 | 275 | 11914 | 273 | 121 | 282 | 70 | 277 | 43 | 284 | 21528 | 280 | 2919 |
| 316 | 50 | 305 | 12651 | 303 | 130 | 312 | 75 | 307 | 48 | 314 | 22876 | 310 | 3101 |
| 346 | 54 | 335 | 13313 | 333 | 138 | 342 | 80 | 337 | 53 | 344 | 24077 | 340 | 3264 |
| 377 | 56 | 365 | 13894 | 363 | 145 | 372 | 84 | 368 | 57 | 374 | 25141 | 370 | 3408 |
| 407 | 58 | 395 | 14411 | 393 | 152 | 402 | 88 | 398 | 60 | 404 | 26088 | 400 | 3536 |
| 437 | 60 | 425 | 14875 | 423 | 158 | 432 | 92 | 428 | 63 | 434 | 26938 | 430 | 3651 |
| 468 | 61 | 455 | 15287 | 453 | 164 | 462 | 96 | 459 | 66 | 464 | 27700 | 460 | 3753 |
| 498 | 62 | 485 | 15664 | 483 | 170 | 492 | 100 | 489 | 68 | 494 | 28388 | 490 | 3847 |
| 528 | 63 | 515 | 16010 | 513 | 175 | 522 | 104 | 519 | 71 | 524 | 29012 | 521 | 3932 |
| 559 | 64 | 545 | 16327 | 543 | 179 | 552 | 107 | 550 | 73 | 554 | 29583 | 551 | 4010 |
| 589 | 64 | 575 | 16619 | 573 | 184 | 582 | 111 | 580 | 75 | 584 | 30109 | 581 | 4082 |
| 619 | 64 | 605 | 16886 | 603 | 188 | 612 | 114 | 610 | 77 | 614 | 30598 | 611 | 4148 |
| 650 | 65 | 635 | 17130 | 633 | 191 | 642 | 117 | 641 | 78 | 644 | 31052 | 641 | 4209 |
| 680 | 65 | 665 | 17360 | 663 | 194 | 672 | 120 | 671 | 79 | 674 | 31470 | 671 | 4266 |
| 710 | 65 | 695 | 17572 | 693 | 198 | 702 | 122 | 701 | 80 | 704 | 31859 | 701 | 4319 |
| 741 | 65 | 725 | 17768 | 723 | 200 | 732 | 125 | 732 | 80 | 734 | 32222 | 731 | 4368 |
| 771 | 65 | 755 | 17956 | 753 | 203 | 762 | 128 | 762 | 81 | 764 | 32560 | 761 | 4414 |
| 801 | 65 | 785 | 18133 | 783 | 206 | 792 | 130 | 792 | 82 | 794 | 32873 | 792 | 4457 |
| 832 | 65 | 815 | 18299 | 813 | 208 | 822 | 133 | 823 | 83 | 824 | 33167 | 822 | 4498 |
| 862 | 65 | 845 | 18455 | 844 | 212 | 853 | 136 | 853 | 84 | 854 | 33440 | 852 | 4537 |
| 892 | 65 | 875 | 18601 | 874 | 215 | 883 | 140 | 883 | 84 | 884 | 33698 | 882 | 4573 |
| 923 | 65 | 905 | 18740 | 904 | 218 | 913 | 143 | 914 | 85 | 914 | 33942 | 912 | 4608 |
| 953 | 65 | 935 | 18873 | 935 | 222 | 944 | 147 | 944 | 86 | 944 | 34174 | 943 | 4641 |
| 983 | 65 | 965 | 18999 | 965 | 225 | 974 | 150 | 974 | 87 | 974 | 34394 | 973 | 4672 |
| 1014 | 65 | 995 | 19119 | 995 | 228 | 1004 | 153 | 1005 | 87 | 1004 | 34604 | 1003 | 4702 |
| 1044 | 65 | 1025 | 19232 | 1026 | 230 | 1035 | 156 | 1035 | 88 | 1034 | 34804 | 1033 | 4730 |
| 1074 | 65 | 1055 | 19341 | 1056 | 232 | 1065 | 159 | 1065 | 89 | 1064 | 34994 | 1063 | 4757 |
| 1105 | 65 | 1085 | 19445 | 1086 | 234 | 1095 | 162 | 1096 | 89 | 1094 | 35173 | 1094 | 4783 |
| 1135 | 65 | 1115 | 19543 | 1117 | 236 | 1126 | 164 | 1126 | 90 | 1124 | 35342 | 1124 | 4807 |
| 1165 | 65 | 1145 | 19639 | 1147 | 238 | 1156 | 167 | 1156 | 91 | 1154 | 35503 | 1154 | 4831 |
| 1196 | 65 | 1175 | 19732 | 1177 | 240 | 1186 | 169 | 1187 | 91 | 1184 | 35659 | 1184 | 4854 |
| 1226 | 65 | 1205 | 19820 | 1208 | 241 | 1217 | 172 | 1217 | 92 | 1214 | 35807 | 1215 | 4875 |
| 1256 | 65 | 1235 | 19904 | 1238 | 243 | 1247 | 174 | 1247 | 93 | 1244 | 35949 | 1245 | 4896 |
| 1287 | 65 | 1265 | 19985 | 1268 | 245 | 1277 | 177 | 1278 | 94 | 1274 | 36084 | 1275 | 4916 |
| 1317 | 65 | 1295 | 20063 | 1299 | 246 | 1308 | 179 | 1308 | 94 | 1304 | 36213 | 1305 | 4935 |
| 1347 | 65 | 1325 | 20137 | 1329 | 248 | 1338 | 181 | 1338 | 95 | 1334 | 36336 | 1335 | 4953 |
| 1378 | 65 | 1355 | 20209 | 1359 | 249 | 1368 | 184 | 1369 | 95 | 1364 | 36453 | 1366 | 4971 |
| 1408 | 65 | 1385 | 20278 | 1390 | 251 | 1399 | 186 | 1399 | 95 | 1394 | 36567 | 1396 | 4988 |
| | | 1415 | 20344 | 1420 | 252 | 1429 | 188 | 1429 | 95 | 1424 | 36676 | 1424 | 4984 |

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_t = 0.3(\text{suit chest material } M_t) + 0.3(\text{suit leg material } M_t) + 0.15(\text{suit arm seam } M_t) + 0.15(\text{hood seam } M_t) + 0.05(\text{boot seam } M_t) + 0.05(\text{zipper seam } M_t)$

Lakeland Coverall, Style 94165

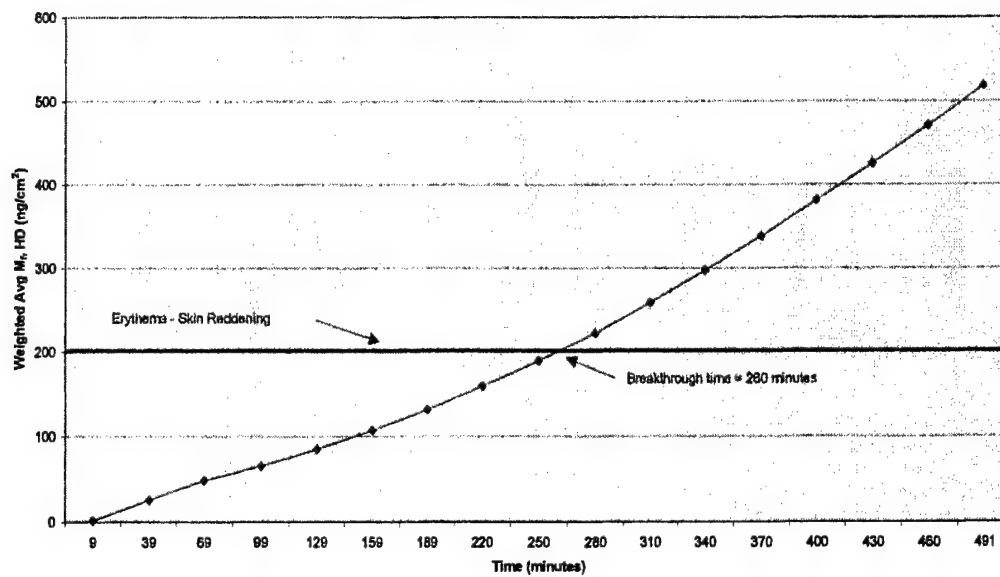


Figure C - 2. Lakeland Coverall - Weighted Average HD Permeation

Lakeland Coverall, Style 94165

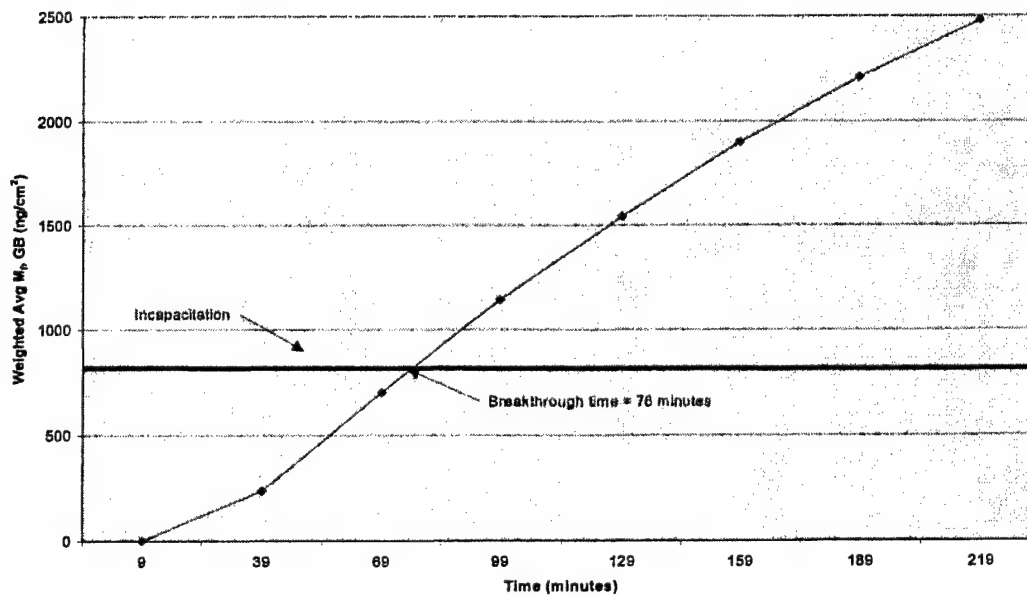


Figure C - 3. Lakeland Coverall - Weighted Average GB Permeation

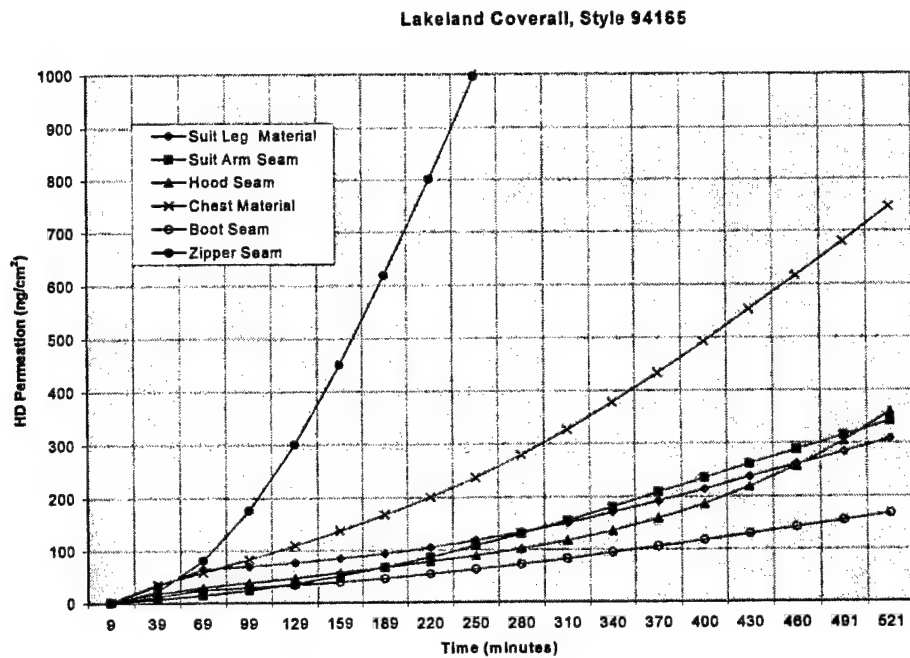


Figure C - 4. Lakeland Coverall - HD Permeation by Sampling Area

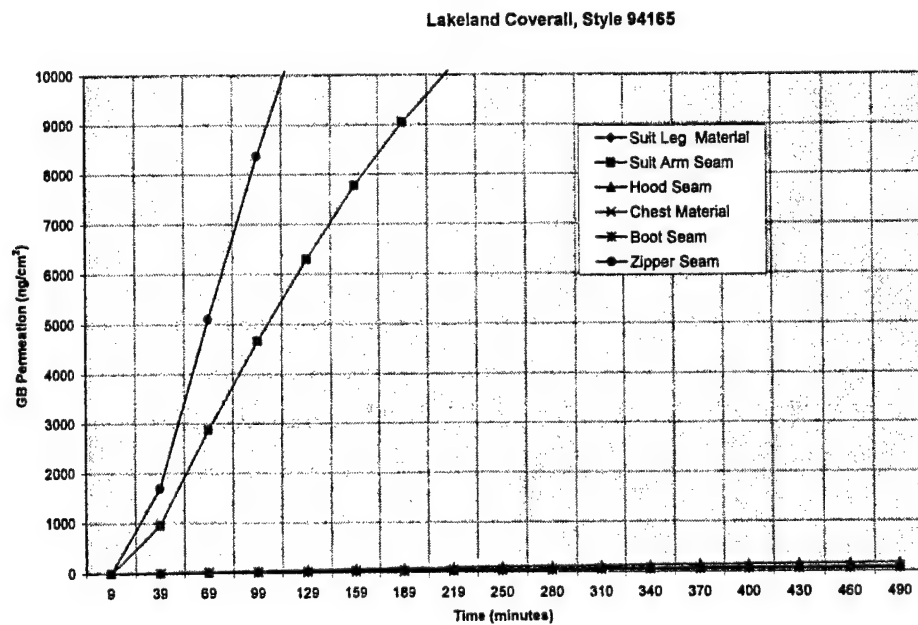


Figure C - 5. Lakeland Coverall - GB Permeation by Sampling Area

Table C - 3. Lakeland Coverall - System Test (Aerosol Simulant) Results

| PF | Visor Region and Upper Arm, Combined | | | | | |
|---------------|--------------------------------------|--------------------------|-------------------------------|-----------------------|--------------------------|-------------------------------|
| | Pre-Operational Exercises | | | Operational Exercises | | |
| | Frequency | Cumulative Rate, Percent | Cumulative Pass Rate, Percent | Frequency | Cumulative Rate, Percent | Cumulative Pass Rate, Percent |
| 0 | 0 | .00 | 100.00 | 0 | .00 | 100.00 |
| 2 | 13 | 54.17 | 45.83 | 13 | 54.17 | 45.83 |
| 5 | 9 | 91.67 | 8.33 | 9 | 91.67 | 8.33 |
| 10 | 2 | 100.00 | .00 | 2 | 100.00 | .00 |
| 50 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 100 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 150 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 500 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 1000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 1667 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 2000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 5000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 6667 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 10000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 20000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 50000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 100000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| No. of Trials | 24 | | | 24 | | |

Table C - 4. Lakeland Coverall - Overall Test Results

| Physiologically-derived breakthrough time (minutes) | | Aerosol PF Pass Rate (%) at PF Equal to: | | | Exercise Phase |
|---|----------|--|---|----|-----------------|
| Incapacitation | Erythema | | | | |
| GB | HD | 2 | 5 | 10 | |
| 76 | 260 | 46 | 8 | 0 | Pre-Operational |
| | | 46 | 8 | 0 | Operational |

Appendix D

Mar Mac Coverall Model 94124



Figure D - 1. Mar Mac 94124 - Front View

Table D - 1. Mar Mac 94124 - Average HD Permeation

| Average Cumulative Permeation (ng/cm ²) | | | | | | | | | | | | | |
|---|-------------------|------------|---------------|------------|---------------|------------|-----------------|------------|-----------|------------|-------------|--------------------|---------------------------------|
| Time (min) | Suit Leg Material | Time (min) | Suit Arm Seam | Time (min) | Hood Material | Time (min) | Crotch Material | Time (min) | Boot Seam | Time (min) | Zipper Seam | Average Time (min) | Weighted Average M _f |
| 12 | 6 | 5 | 4 | 3 | 4 | 13 | 1 | 4 | 0 | 14 | 5 | 8 | 4 |
| 43 | 24 | 35 | 30 | 34 | 53 | 43 | 4 | 34 | 3 | 44 | 37 | 39 | 25 |
| 73 | 34 | 65 | 40 | 64 | 64 | 73 | 7 | 64 | 7 | 74 | 98 | 69 | 36 |
| 104 | 46 | 95 | 48 | 94 | 77 | 104 | 9 | 95 | 10 | 104 | 186 | 99 | 49 |
| 134 | 57 | 125 | 59 | 125 | 88 | 134 | 12 | 125 | 14 | 134 | 286 | 129 | 63 |
| 164 | 68 | 155 | 73 | 155 | 101 | 164 | 17 | 155 | 20 | 164 | 395 | 160 | 78 |
| 195 | 80 | 185 | 88 | 185 | 116 | 195 | 22 | 186 | 28 | 194 | 513 | 190 | 95 |
| 225 | 93 | 215 | 107 | 216 | 136 | 225 | 28 | 216 | 39 | 224 | 632 | 220 | 114 |
| 255 | 107 | 245 | 129 | 246 | 159 | 255 | 36 | 246 | 52 | 254 | 752 | 250 | 134 |
| 286 | 122 | 275 | 156 | 276 | 190 | 286 | 46 | 277 | 68 | 284 | 874 | 280 | 157 |
| 316 | 138 | 305 | 187 | 307 | 227 | 316 | 56 | 307 | 88 | 314 | 1002 | 311 | 183 |
| 346 | 158 | 335 | 223 | 337 | 266 | 346 | 68 | 337 | 111 | 344 | 1133 | 341 | 212 |
| 377 | 181 | 365 | 260 | 367 | 307 | 377 | 81 | 368 | 137 | 374 | 1263 | 371 | 242 |
| 407 | 203 | 395 | 299 | 398 | 350 | 407 | 95 | 398 | 166 | 404 | 1400 | 401 | 274 |
| 437 | 224 | 425 | 338 | 428 | 392 | 437 | 109 | 428 | 196 | 434 | 1539 | 431 | 305 |
| 468 | 246 | 455 | 379 | 458 | 434 | 468 | 123 | 459 | 225 | 464 | 1678 | 462 | 337 |
| 498 | 269 | 485 | 420 | 489 | 477 | 498 | 137 | 489 | 254 | 494 | 1822 | 492 | 370 |
| 528 | 293 | 515 | 461 | 519 | 520 | 528 | 151 | 519 | 283 | 524 | 1968 | 522 | 403 |
| 559 | 315 | 545 | 502 | 549 | 564 | 559 | 166 | 550 | 311 | 554 | 2115 | 552 | 435 |
| 589 | 336 | 575 | 543 | 580 | 607 | 589 | 180 | 580 | 340 | 584 | 2264 | 583 | 468 |
| 619 | 358 | 605 | 584 | 610 | 648 | 619 | 195 | 610 | 370 | 614 | 2413 | 613 | 500 |
| 650 | 379 | 635 | 624 | 640 | 689 | 650 | 209 | 640 | 398 | 644 | 2565 | 643 | 531 |
| 680 | 400 | 665 | 663 | 671 | 728 | 680 | 223 | 671 | 426 | 674 | 2722 | 673 | 563 |
| 710 | 421 | 695 | 702 | 701 | 765 | 710 | 237 | 701 | 453 | 704 | 2880 | 703 | 594 |
| 741 | 441 | 725 | 741 | 731 | 802 | 741 | 251 | 731 | 480 | 734 | 3034 | 734 | 625 |
| 771 | 460 | 755 | 780 | 762 | 838 | 771 | 265 | 762 | 506 | 764 | 3189 | 764 | 655 |
| 801 | 479 | 785 | 818 | 792 | 873 | 801 | 278 | 792 | 530 | 794 | 3345 | 794 | 685 |
| 832 | 498 | 815 | 856 | 822 | 906 | 831 | 291 | 822 | 554 | 824 | 3503 | 824 | 715 |
| 862 | 517 | 845 | 895 | 853 | 939 | 862 | 304 | 853 | 577 | 854 | 3666 | 855 | 744 |
| 892 | 535 | 875 | 932 | 883 | 972 | 892 | 316 | 883 | 600 | 884 | 3833 | 885 | 773 |
| 923 | 551 | 905 | 967 | 913 | 1004 | 922 | 328 | 913 | 623 | 914 | 4007 | 915 | 802 |
| 953 | 568 | 935 | 1002 | 944 | 1035 | 953 | 341 | 944 | 643 | 944 | 4187 | 945 | 830 |
| 983 | 584 | 965 | 1039 | 974 | 1066 | 983 | 353 | 974 | 663 | 974 | 4372 | 975 | 859 |
| 1014 | 601 | 995 | 1076 | 1004 | 1096 | 1013 | 364 | 1004 | 682 | 1004 | 4559 | 1006 | 888 |
| 1044 | 617 | 1025 | 1114 | 1035 | 1127 | 1044 | 376 | 1035 | 701 | 1034 | 4749 | 1036 | 917 |
| 1074 | 633 | 1055 | 1151 | 1065 | 1156 | 1074 | 386 | 1065 | 719 | 1064 | 4944 | 1066 | 946 |
| 1105 | 649 | 1085 | 1186 | 1095 | 1183 | 1104 | 397 | 1095 | 737 | 1094 | 5140 | 1096 | 974 |
| 1135 | 664 | 1115 | 1221 | 1126 | 1210 | 1135 | 407 | 1125 | 755 | 1124 | 5333 | 1126 | 1002 |
| 1165 | 679 | 1145 | 1255 | 1156 | 1236 | 1165 | 418 | 1156 | 771 | 1154 | 5526 | 1157 | 1029 |
| 1196 | 693 | 1175 | 1287 | 1186 | 1260 | 1195 | 428 | 1186 | 788 | 1184 | 5716 | 1187 | 1055 |
| 1226 | 709 | 1205 | 1317 | 1217 | 1286 | 1226 | 438 | 1216 | 804 | 1214 | 5902 | 1217 | 1082 |
| 1256 | 724 | 1235 | 1347 | 1247 | 1312 | 1256 | 449 | 1247 | 820 | 1244 | 6088 | 1247 | 1108 |
| 1287 | 739 | 1265 | 1377 | 1277 | 1337 | 1286 | 459 | 1277 | 836 | 1274 | 6275 | 1278 | 1134 |
| 1317 | 754 | 1295 | 1406 | 1308 | 1360 | 1317 | 469 | 1307 | 851 | 1304 | 6461 | 1308 | 1160 |
| 1347 | 768 | 1325 | 1435 | 1338 | 1383 | 1347 | 479 | 1338 | 865 | 1334 | 6646 | 1338 | 1185 |
| 1378 | 782 | 1355 | 1462 | 1368 | 1405 | 1377 | 488 | 1368 | 879 | 1364 | 6831 | 1368 | 1210 |
| 1408 | 796 | 1385 | 1489 | 1399 | 1427 | 1407 | 497 | 1398 | 893 | 1394 | 7014 | 1398 | 1234 |
| | | 1415 | 1516 | 1429 | 1448 | | | 1429 | 908 | 1424 | 7198 | | |

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_f = 0.5(\text{Suit Matl } M_f) + 0.15(\text{Suit Seam } M_f) + 0.15(\text{Crotch Matl } M_f) + 0.1(\text{Hood Matl } M_f) + 0.05(\text{Boot Seam } M_f) + 0.05(\text{Zipper Seam } M_f)$.

Table D - 2. Mar Mac 94124 - Average GB Permeation

| Average Cumulative Permeation (ng/cm ²) | | | | | | | | | | | | | |
|---|-------------------|------------|---------------|------------|---------------|------------|-----------------|------------|-----------|------------|-------------|--------------------|---------------------------------|
| Time (min) | Suit Leg Material | Time (min) | Suit Arm Seam | Time (min) | Hood Material | Time (min) | Crotch Material | Time (min) | Boot Seam | Time (min) | Zipper Seam | Average Time (min) | Weighted Average M _t |
| 13 | 5 | 5 | 2 | 4 | 2 | 13 | 39 | 4 | 22 | 14 | 3 | 9 | 10 |
| 43 | 21 | 35 | 18 | 34 | 30 | 44 | 307 | 35 | 1602 | 44 | 1503 | 39 | 218 |
| 73 | 33 | 66 | 39 | 64 | 56 | 74 | 698 | 65 | 4695 | 75 | 4473 | 69 | 591 |
| 103 | 45 | 96 | 64 | 94 | 82 | 104 | 1139 | 95 | 8028 | 105 | 7319 | 100 | 979 |
| 133 | 58 | 126 | 83 | 124 | 108 | 134 | 1589 | 125 | 11386 | 135 | 9887 | 130 | 1354 |
| 163 | 70 | 157 | 100 | 154 | 132 | 165 | 2025 | 155 | 14715 | 166 | 12175 | 160 | 1712 |
| 193 | 82 | 187 | 114 | 184 | 155 | 195 | 2437 | 186 | 17999 | 196 | 14230 | 190 | 2051 |
| 223 | 95 | 217 | 127 | 214 | 178 | 225 | 2826 | 216 | 21207 | 226 | 16075 | 220 | 2372 |
| 253 | 107 | 248 | 139 | 244 | 199 | 255 | 3192 | 246 | 24319 | 257 | 17742 | 251 | 2676 |
| 283 | 119 | 278 | 149 | 274 | 220 | 286 | 3540 | 276 | 27334 | 287 | 19229 | 281 | 2963 |
| 313 | 130 | 308 | 159 | 304 | 239 | 316 | 3866 | 307 | 30245 | 317 | 20565 | 311 | 3233 |
| 343 | 141 | 339 | 169 | 334 | 257 | 346 | 4170 | 337 | 32944 | 348 | 21777 | 341 | 3483 |
| 373 | 150 | 369 | 177 | 364 | 274 | 376 | 4459 | 367 | 35413 | 378 | 22874 | 371 | 3712 |
| 403 | 160 | 399 | 185 | 394 | 291 | 403 | 4628 | | | 408 | 23873 | | |
| 433 | 168 | 430 | 192 | 424 | 306 | 431 | 4711 | | | 439 | 24778 | | |
| 463 | 177 | 460 | 198 | 454 | 321 | 458 | 4790 | | | 469 | 25609 | | |
| 493 | 186 | 490 | 204 | 484 | 336 | 485 | 4867 | | | 499 | 26383 | | |
| 523 | 197 | 521 | 209 | 514 | 351 | 512 | 4943 | | | 530 | 27090 | | |
| 553 | 207 | 551 | 214 | 544 | 365 | 540 | 5017 | | | 560 | 27736 | | |
| 583 | 216 | 581 | 219 | 574 | 379 | 567 | 5090 | | | 590 | 28335 | | |
| 613 | 224 | 612 | 224 | 604 | 392 | 594 | 5162 | | | 621 | 28891 | | |
| 643 | 231 | 642 | 228 | 634 | 404 | 621 | 5232 | | | 651 | 29405 | | |
| 673 | 238 | 672 | 232 | 664 | 416 | 648 | 5301 | | | 681 | 29879 | | |
| 703 | 244 | 703 | 236 | 694 | 427 | 676 | 5368 | | | 712 | 30323 | | |
| 733 | 251 | 733 | 240 | 724 | 437 | 703 | 5433 | | | 742 | 30741 | | |
| 763 | 257 | 763 | 243 | 754 | 448 | 730 | 5497 | | | 772 | 31134 | | |
| 793 | 263 | 793 | 247 | 784 | 457 | 757 | 5561 | | | 803 | 31503 | | |
| 823 | 268 | 824 | 250 | 814 | 466 | 785 | 5622 | | | 833 | 31850 | | |
| 853 | 273 | 854 | 253 | 844 | 475 | 812 | 5681 | | | 863 | 32177 | | |
| 883 | 278 | 884 | 256 | 874 | 484 | 839 | 5737 | | | 894 | 32489 | | |
| 913 | 283 | 915 | 258 | 904 | 492 | 866 | 5792 | | | 924 | 32785 | | |
| 943 | 287 | 945 | 261 | 934 | 499 | 894 | 5846 | | | 954 | 33065 | | |
| 973 | 291 | 975 | 264 | 964 | 507 | 921 | 5900 | | | 985 | 33327 | | |
| 1003 | 295 | 1006 | 266 | 994 | 514 | 948 | 5951 | | | 1015 | 33576 | | |
| 1033 | 300 | 1036 | 269 | 1024 | 521 | 975 | 6002 | | | 1045 | 33813 | | |
| 1063 | 304 | 1066 | 271 | 1054 | 528 | 1002 | 6051 | | | 1076 | 34037 | | |
| 1093 | 309 | 1097 | 273 | 1084 | 535 | 1030 | 6099 | | | 1106 | 34248 | | |
| 1123 | 313 | 1127 | 275 | 1114 | 543 | 1057 | 6146 | | | 1136 | 34452 | | |
| 1153 | 318 | 1157 | 278 | 1144 | 552 | 1084 | 6191 | | | 1167 | 34647 | | |
| 1183 | 322 | 1188 | 280 | 1174 | 560 | 1111 | 6237 | | | 1197 | 34834 | | |
| 1213 | 326 | 1218 | 282 | 1204 | 567 | 1139 | 6281 | | | 1227 | 35013 | | |
| 1243 | 329 | 1248 | 284 | 1234 | 574 | 1166 | 6324 | | | 1258 | 35184 | | |
| 1273 | 333 | 1279 | 286 | 1264 | 581 | 1193 | 6366 | | | 1288 | 35352 | | |
| 1303 | 336 | 1309 | 288 | 1294 | 587 | 1220 | 6406 | | | 1318 | 35517 | | |
| 1333 | 339 | 1339 | 290 | 1324 | 594 | 1247 | 6446 | | | 1349 | 35681 | | |
| 1363 | 342 | 1370 | 292 | 1354 | 600 | 1275 | 6485 | | | 1379 | 35841 | | |

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_t = 0.5(\text{Suit Matl } M_t) + 0.15(\text{Suit Seam } M_t) + 0.15(\text{Crotch Matl } M_t) + 0.1(\text{Hood Matl } M_t) + 0.05(\text{Boot Seam } M_t) + 0.05(\text{Zipper Seam } M_t)$.

Note 4: Sampling for boot seam was ended prematurely due to equipment failure.

MarMac Coverall Model 94124

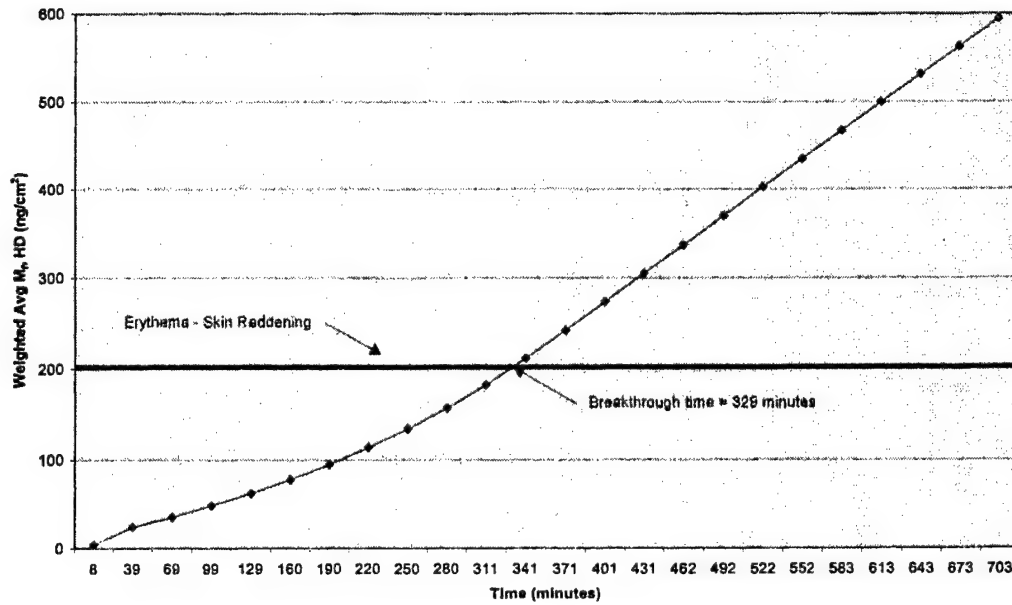


Figure D - 2. Mar Mac 94124 - Weighted Average HD Permeation

MarMac Coverall Model 94124

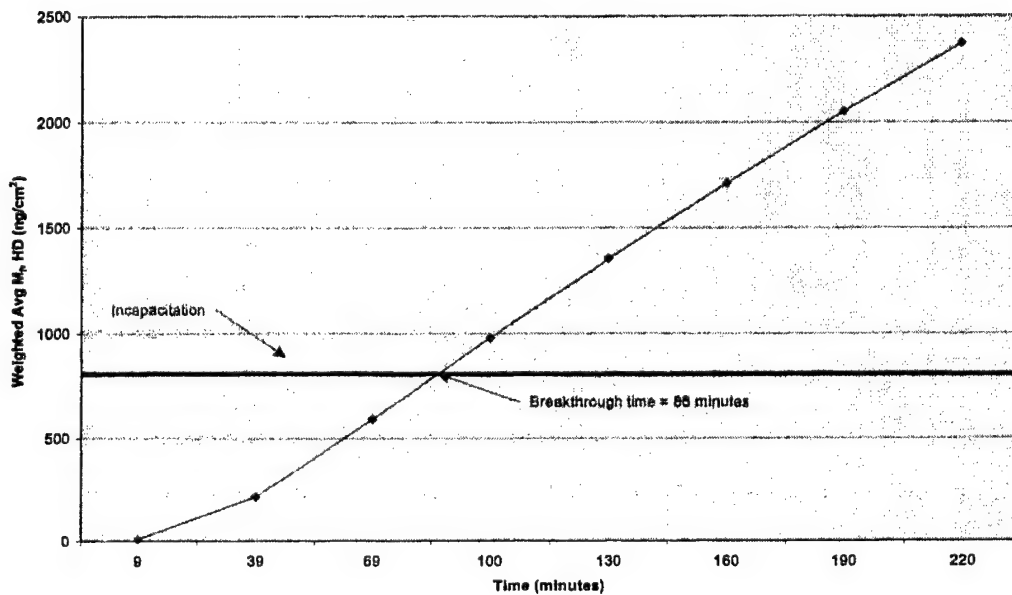


Figure D - 3. Mar Mac 94124 - Weighted Average GB Permeation

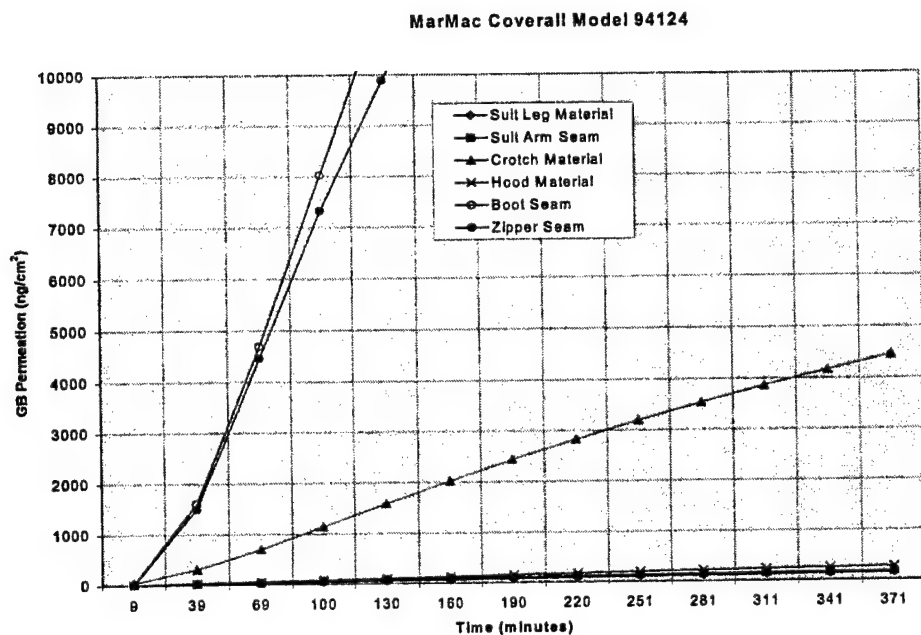


Figure D - 4. Mar Mac 94124 - HD Permeation by Sampling Area

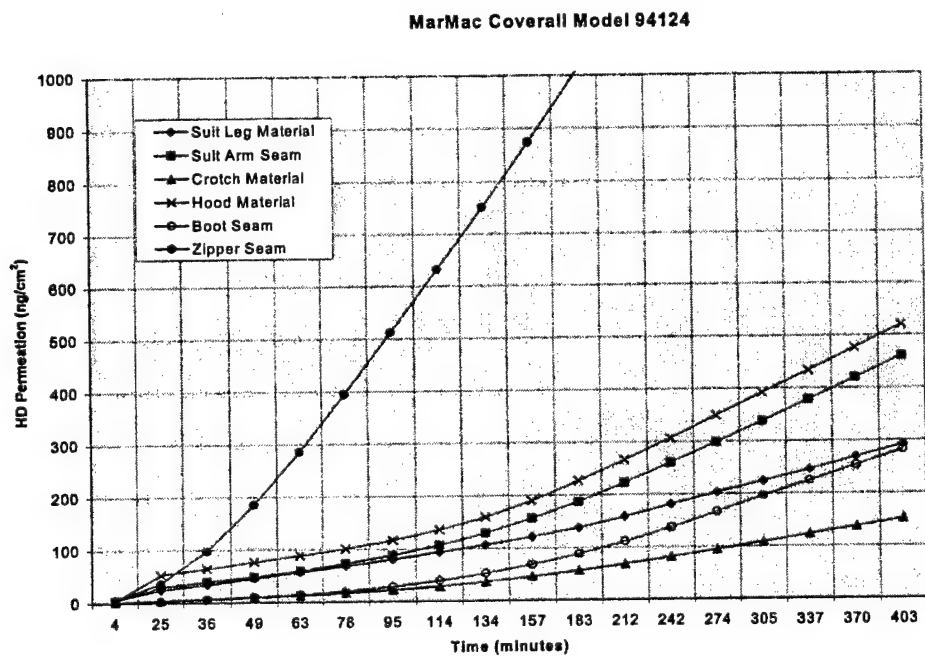


Figure D - 5. Mar Mac 94124 - GB Permeation by Sampling Area.

Table D - 3. Mar Mac 94124 - System Test (Aerosol Simulant) Results

| PF | Visor Region and Upper Arm, Combined | | | | | |
|---------------|--------------------------------------|--------------------------|-------------------------------|-----------------------|--------------------------|-------------------------------|
| | Pre-Operational Exercises | | | Operational Exercises | | |
| | Frequency | Cumulative Rate, Percent | Cumulative Pass Rate, Percent | Frequency | Cumulative Rate, Percent | Cumulative Pass Rate, Percent |
| 0 | 0 | .00 | 100.00 | 0 | .00 | 100.00 |
| 2 | 12 | 50.00 | 50.00 | 12 | 50.00 | 50.00 |
| 5 | 6 | 75.00 | 25.00 | 9 | 87.50 | 12.50 |
| 10 | 6 | 100.00 | .00 | 3 | 100.00 | .00 |
| 50 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 100 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 150 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 500 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 1000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 1667 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 2000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 5000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 6667 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 10000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 20000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 50000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 100000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| No. of Trials | 24 | | | 24 | | |

Table D - 4. Mar Mac 94124 - Overall Test Results

| Physiologically-derived breakthrough time (minutes) | | Aerosol PF Pass Rate (%) at PF Equal to: | | | Exercise Phase |
|---|----------|--|----|----|-----------------|
| Incapacitation | Erythema | | | | |
| GB | HD | 2 | 5 | 10 | |
| 86 | 329 | 50 | 25 | 0 | Pre-Operational |
| | | 50 | 13 | 0 | Operational |

Appendix E

Mar Mac Coverall Model 100124



Figure E - 1. Mar Mac 100124 - Front View

Table E - 1. Mar Mac 100124 - Average HD Permeation

| Average Cumulative Permeation (ng/cm ²) | | | | | | | | | | | | | |
|---|-------------------|------------|---------------|------------|---------------|------------|-----------------|------------|-----------|------------|-------------|--------------------|---------------------------------|
| Time (min) | Suit Leg Material | Time (min) | Suit Arm Seam | Time (min) | Hood Material | Time (min) | Crotch Material | Time (min) | Boot Seam | Time (min) | Zipper Seam | Average Time (min) | Weighted Average M _f |
| 14 | 1 | 12 | 6 | 4 | 1 | 13 | 9 | 5 | 0 | 3 | 3 | 9 | 3 |
| 45 | 4 | 42 | 32 | 34 | 28 | 43 | 46 | 36 | 3 | 33 | 59 | 39 | 18 |
| 75 | 8 | 73 | 49 | 64 | 52 | 73 | 107 | 66 | 5 | 64 | 168 | 69 | 33 |
| 105 | 11 | 103 | 62 | 95 | 66 | 104 | 254 | 96 | 8 | 94 | 339 | 99 | 55 |
| 135 | 14 | 133 | 77 | 125 | 80 | 134 | 543 | 126 | 14 | 124 | 555 | 129 | 92 |
| 165 | 21 | 163 | 94 | 155 | 97 | 164 | 968 | 156 | 27 | 154 | 810 | 160 | 145 |
| 195 | 30 | 193 | 112 | 185 | 117 | 194 | 1497 | 186 | 45 | 184 | 1099 | 190 | 211 |
| 226 | 42 | 224 | 133 | 215 | 141 | 224 | 2111 | 217 | 72 | 214 | 1410 | 220 | 287 |
| 256 | 57 | 254 | 155 | 246 | 167 | 255 | 2774 | 247 | 108 | 245 | 1734 | 250 | 372 |
| 286 | 75 | 284 | 179 | 276 | 196 | 285 | 3479 | 277 | 149 | 275 | 2068 | 280 | 463 |
| 316 | 95 | 314 | 204 | 306 | 228 | 315 | 4199 | 307 | 193 | 305 | 2406 | 311 | 557 |
| 346 | 119 | 344 | 230 | 336 | 262 | 345 | 4907 | 337 | 241 | 335 | 2743 | 341 | 653 |
| 377 | 143 | 374 | 257 | 366 | 298 | 375 | 5622 | 367 | 292 | 365 | 3080 | 371 | 750 |
| 407 | 167 | 405 | 284 | 396 | 334 | 406 | 6347 | 398 | 344 | 396 | 3416 | 401 | 848 |
| 437 | 192 | 435 | 312 | 427 | 370 | 436 | 7073 | 428 | 396 | 426 | 3758 | 431 | 947 |
| 467 | 217 | 465 | 342 | 457 | 407 | 466 | 7801 | 458 | 447 | 456 | 4102 | 461 | 1046 |
| 497 | 241 | 495 | 373 | 487 | 444 | 496 | 8517 | 488 | 496 | 486 | 4451 | 492 | 1144 |
| 527 | 266 | 525 | 404 | 517 | 481 | 526 | 9218 | 518 | 545 | 516 | 4807 | 522 | 1240 |
| 558 | 290 | 555 | 437 | 547 | 517 | 556 | 9929 | 549 | 592 | 546 | 5167 | 552 | 1338 |
| 588 | 314 | 586 | 470 | 578 | 552 | 587 | 10633 | 579 | 637 | 577 | 5533 | 582 | 1434 |
| 618 | 337 | 616 | 504 | 608 | 588 | 617 | 11309 | 609 | 682 | 607 | 5906 | 612 | 1528 |
| 648 | 359 | 646 | 540 | 638 | 623 | 647 | 11974 | 639 | 726 | 637 | 6282 | 643 | 1620 |
| 678 | 382 | 676 | 576 | 668 | 657 | 677 | 12629 | 669 | 766 | 667 | 6662 | 673 | 1711 |
| 709 | 403 | 706 | 612 | 698 | 691 | 707 | 13269 | 700 | 806 | 697 | 7048 | 703 | 1799 |
| 739 | 424 | 737 | 647 | 729 | 723 | 738 | 13888 | 730 | 845 | 727 | 7438 | 733 | 1885 |
| 769 | 444 | 767 | 683 | 759 | 756 | 768 | 14490 | 760 | 883 | 758 | 7830 | 763 | 1969 |
| 799 | 464 | 797 | 718 | 789 | 788 | 798 | 15082 | 790 | 920 | 788 | 8219 | 793 | 2052 |
| 829 | 483 | 827 | 754 | 819 | 819 | 828 | 15673 | 820 | 956 | 818 | 8603 | 824 | 2134 |
| 860 | 502 | 857 | 790 | 849 | 850 | 858 | 16254 | 850 | 992 | 848 | 8987 | 854 | 2215 |
| 890 | 521 | 887 | 826 | 880 | 880 | 889 | 16817 | 881 | 1025 | 878 | 9376 | 884 | 2293 |
| 920 | 540 | 918 | 862 | 910 | 910 | 919 | 17364 | 911 | 1057 | 909 | 9768 | 914 | 2370 |
| 950 | 557 | 948 | 897 | 940 | 938 | 949 | 17887 | 941 | 1089 | 939 | 10165 | 944 | 2444 |
| 980 | 575 | 978 | 933 | 970 | 967 | 979 | 18401 | 971 | 1119 | 969 | 10557 | 975 | 2517 |
| 1010 | 592 | 1008 | 968 | 1000 | 994 | 1009 | 18917 | 1001 | 1149 | 999 | 10938 | 1005 | 2589 |
| 1041 | 609 | 1038 | 1004 | 1030 | 1021 | 1040 | 19419 | 1032 | 1179 | 1029 | 11317 | 1035 | 2660 |
| 1071 | 625 | 1068 | 1039 | 1061 | 1049 | 1070 | 19908 | 1062 | 1207 | 1059 | 11688 | 1065 | 2730 |
| 1101 | 642 | 1099 | 1074 | 1091 | 1075 | 1100 | 20381 | 1092 | 1235 | 1090 | 12047 | 1095 | 2798 |
| 1131 | 658 | 1129 | 1108 | 1121 | 1100 | 1130 | 20831 | 1122 | 1262 | 1120 | 12399 | 1126 | 2862 |
| 1161 | 673 | 1159 | 1142 | 1151 | 1125 | 1160 | 21273 | 1152 | 1288 | 1150 | 12741 | 1156 | 2926 |
| 1192 | 687 | 1189 | 1175 | 1181 | 1148 | 1191 | 21703 | 1183 | 1314 | 1180 | 13075 | 1186 | 2987 |
| 1222 | 700 | 1219 | 1208 | 1212 | 1169 | 1221 | 22112 | 1213 | 1338 | 1210 | 13406 | 1216 | 3045 |
| 1252 | 713 | 1250 | 1240 | 1242 | 1190 | 1251 | 22512 | 1243 | 1363 | 1240 | 13730 | 1246 | 3102 |
| 1282 | 726 | 1280 | 1270 | 1272 | 1209 | 1281 | 22905 | 1273 | 1387 | 1271 | 14043 | 1276 | 3159 |
| 1312 | 739 | 1310 | 1300 | 1302 | 1228 | 1311 | 23285 | 1303 | 1410 | 1301 | 14341 | 1307 | 3213 |
| 1343 | 752 | 1340 | 1328 | 1333 | 1248 | 1342 | 23658 | 1333 | 1433 | 1331 | 14628 | 1337 | 3266 |
| 1373 | 764 | 1370 | 1357 | 1363 | 1267 | 1372 | 24024 | 1364 | 1455 | 1361 | 14904 | 1367 | 3319 |
| 1403 | 776 | 1400 | 1385 | 1393 | 1285 | 1402 | 24389 | 1394 | 1476 | 1391 | 15170 | 1397 | 3371 |
| 1433 | 787 | 1431 | 1412 | 1423 | 1303 | 1432 | 24751 | 1424 | 1498 | 1422 | 15431 | 1427 | 3422 |

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_f = 0.5(\text{Suit Matl } M_f) + 0.15(\text{Suit Seam } M_f) + 0.15(\text{Hood Matl } M_f) + 0.1(\text{Crotch Matl } M_f) + 0.05(\text{Boot Seam } M_f) + 0.05(\text{Zipper Seam } M_f)$.

Table E - 2. Mar Mac 100124 - Average GB Permeation

| Average Cumulative Permeation (ng/cm ²) | | | | | | | | | | | | | |
|---|-------------------|------------|---------------|------------|---------------|------------|-----------------|------------|-----------|------------|-------------|--------------------|---------------------------------|
| Time (min) | Suit Leg Material | Time (min) | Suit Arm Seam | Time (min) | Hood Material | Time (min) | Crotch Material | Time (min) | Boot Seam | Time (min) | Zipper Seam | Average Time (min) | Weighted Average M _p |
| 12 | 3 | 15 | 4 | 3 | 1 | 13 | 0 | 4 | 0 | 6 | 2 | 9 | 2 |
| 42 | 15 | 45 | 251 | 33 | 24 | 43 | 29 | 34 | 252 | 36 | 2329 | 39 | 66 |
| 72 | 23 | 75 | 984 | 63 | 37 | 73 | 84 | 64 | 1235 | 66 | 7515 | 69 | 238 |
| 102 | 27 | 105 | 1902 | 93 | 45 | 103 | 139 | 94 | 2735 | 96 | 13315 | 99 | 461 |
| 132 | 31 | 136 | 2679 | 123 | 51 | 133 | 193 | 124 | 4241 | 126 | 19162 | 129 | 663 |
| 162 | 34 | 166 | 3325 | 153 | 56 | 163 | 244 | 154 | 5657 | 157 | 24950 | 159 | 839 |
| 192 | 37 | 196 | 3866 | 183 | 60 | 193 | 292 | 184 | 6934 | 187 | 30611 | 189 | 992 |
| 222 | 39 | 226 | 4329 | 213 | 64 | 223 | 337 | 214 | 8074 | 217 | 36103 | 219 | 1127 |
| 252 | 41 | 256 | 4735 | 243 | 68 | 253 | 380 | 244 | 9089 | 247 | 41302 | 249 | 1246 |
| 282 | 43 | 286 | 5096 | 273 | 71 | 283 | 419 | 274 | 9973 | 277 | 46024 | 279 | 1351 |
| 312 | 45 | 317 | 5421 | 303 | 75 | 313 | 457 | 304 | 10746 | 308 | 50338 | 309 | 1445 |
| 342 | 47 | 347 | 5716 | 333 | 78 | 343 | 492 | 334 | 11415 | 338 | 54379 | 339 | 1529 |
| 372 | 49 | 377 | 5985 | 363 | 81 | 373 | 524 | 364 | 11996 | 368 | 58155 | 369 | 1605 |
| 402 | 50 | 407 | 6231 | 393 | 84 | 403 | 554 | 394 | 12505 | 398 | 61644 | 400 | 1673 |
| 432 | 52 | 437 | 6456 | 423 | 86 | 433 | 582 | 424 | 12946 | 428 | 64886 | 430 | 1734 |
| 462 | 54 | 467 | 6663 | 453 | 88 | 463 | 608 | 454 | 13331 | 458 | 67893 | 460 | 1790 |
| 492 | 55 | 498 | 6853 | 483 | 90 | 493 | 632 | 484 | 13663 | 489 | 70677 | 490 | 1839 |
| 522 | 55 | 525 | 7004 | 513 | 92 | 523 | 653 | 514 | 13949 | | | | |
| 552 | 56 | 549 | 7115 | 543 | 93 | 553 | 674 | 544 | 14200 | | | | |
| 582 | 57 | 573 | 7210 | 573 | 95 | 583 | 692 | 574 | 14419 | | | | |
| 612 | 57 | 597 | 7301 | 603 | 96 | 613 | 710 | 604 | 14614 | | | | |
| 642 | 57 | 621 | 7386 | 633 | 98 | 643 | 726 | 634 | 14787 | | | | |
| 672 | 57 | 646 | 7467 | 663 | 99 | 673 | 741 | 664 | 14941 | | | | |
| 702 | 57 | 670 | 7542 | 693 | 101 | 703 | 756 | 694 | 15080 | | | | |
| 732 | 57 | 694 | 7613 | 723 | 102 | 733 | 769 | 724 | 15204 | | | | |
| 762 | 57 | 718 | 7682 | 753 | 103 | 763 | 781 | 754 | 15317 | | | | |
| 792 | 57 | 742 | 7748 | 783 | 105 | 793 | 793 | 784 | 15419 | | | | |
| 822 | 57 | 766 | 7811 | 813 | 106 | 823 | 804 | 814 | 15512 | | | | |
| 852 | 57 | 790 | 7871 | 843 | 107 | 853 | 815 | 844 | 15596 | | | | |
| 882 | 57 | 815 | 7929 | 873 | 108 | 883 | 825 | 874 | 15675 | | | | |
| 912 | 57 | 839 | 7986 | 903 | 109 | 913 | 835 | 904 | 15750 | | | | |
| 942 | 57 | 863 | 8040 | 933 | 111 | 943 | 844 | 934 | 15820 | | | | |
| 972 | 57 | 887 | 8093 | 963 | 112 | 974 | 853 | 965 | 15885 | | | | |
| 1002 | 57 | 911 | 8145 | 993 | 113 | 1004 | 862 | 995 | 15946 | | | | |
| 1032 | 57 | 935 | 8194 | 1023 | 115 | 1034 | 870 | 1025 | 16003 | | | | |
| 1062 | 57 | 959 | 8242 | 1053 | 116 | 1065 | 878 | 1056 | 16055 | | | | |
| 1092 | 57 | 984 | 8289 | 1083 | 117 | 1095 | 885 | 1086 | 16105 | | | | |
| 1122 | 57 | 1008 | 8334 | 1113 | 118 | 1125 | 892 | 1116 | 16152 | | | | |
| 1152 | 57 | 1032 | 8378 | 1143 | 119 | 1156 | 899 | 1147 | 16196 | | | | |
| 1182 | 57 | 1056 | 8421 | 1173 | 120 | 1186 | 906 | 1177 | 16237 | | | | |
| 1212 | 57 | 1080 | 8464 | 1203 | 121 | 1216 | 912 | 1207 | 16276 | | | | |
| 1242 | 57 | 1104 | 8505 | 1233 | 122 | 1247 | 917 | 1238 | 16313 | | | | |
| 1272 | 57 | 1128 | 8546 | 1263 | 123 | 1277 | 922 | 1268 | 16348 | | | | |
| 1302 | 57 | 1153 | 8586 | 1293 | 125 | 1307 | 927 | 1298 | 16380 | | | | |
| 1332 | 57 | 1177 | 8624 | 1323 | 126 | 1338 | 932 | 1329 | 16412 | | | | |
| 1362 | 57 | 1201 | 8662 | 1353 | 127 | 1368 | 936 | 1359 | 16442 | | | | |
| 1392 | 57 | 1225 | 8699 | 1383 | 128 | 1398 | 941 | 1389 | 16471 | | | | |
| 1422 | 57 | 1249 | 8736 | 1413 | 129 | 1429 | 945 | 1420 | 16500 | | | | |

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_p = 0.5(\text{Suit Matl } M_p) + 0.15(\text{Suit Seam } M_p) + 0.15(\text{Hood Matl } M_p) + 0.1(\text{Crotch Matl } M_p) + 0.05(\text{Boot Seam } M_p) + 0.05(\text{Zipper Seam } M_p)$.

Note 4: Sampling for the zipper seam was ended prematurely due to equipment failure.

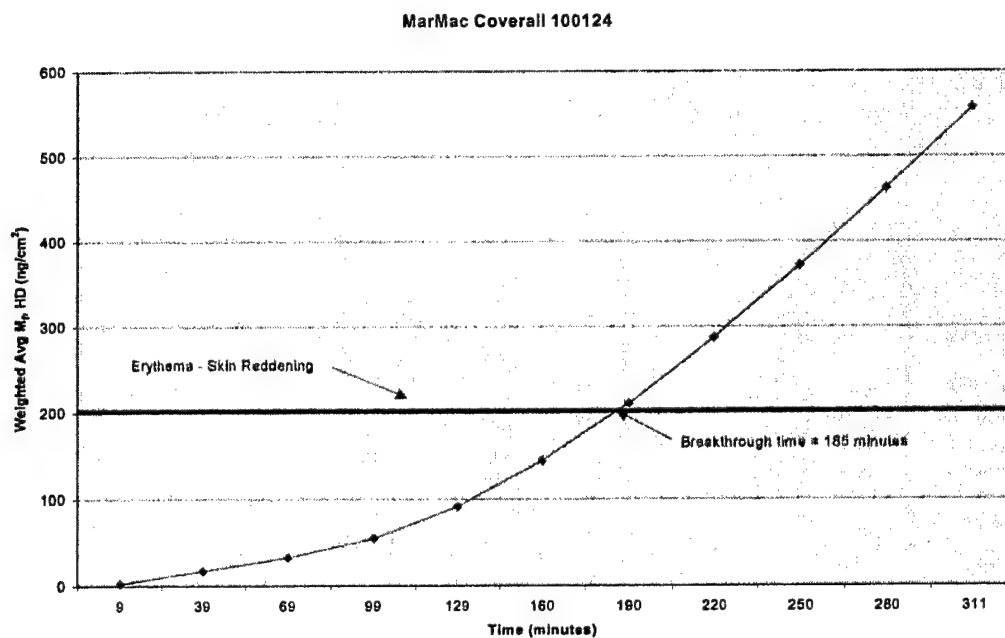


Figure E - 2. Mar Mac 100124 - Weighted Average HD Permeation

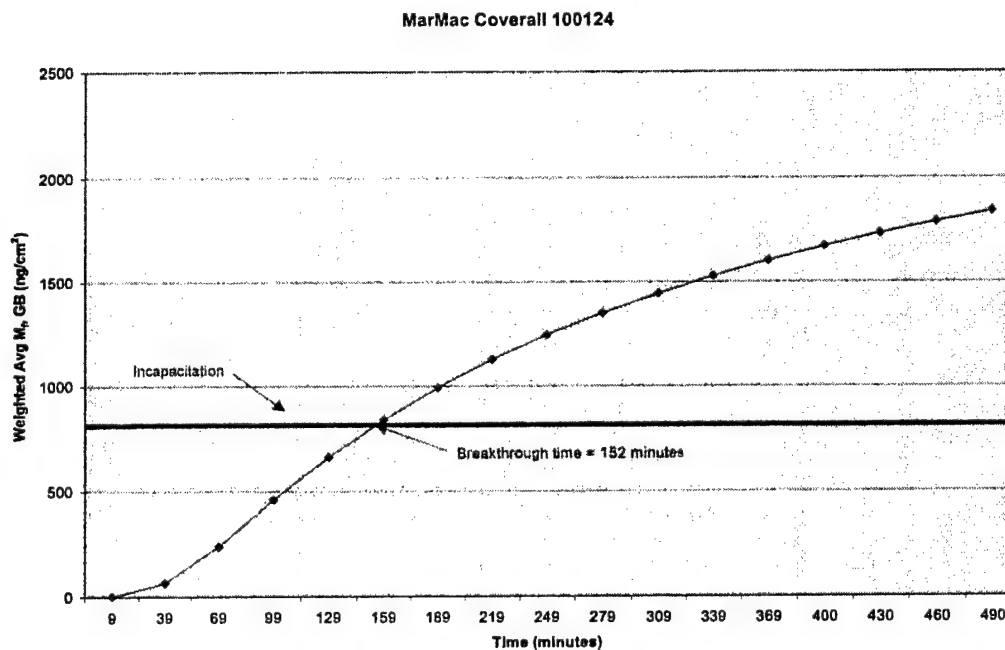


Figure E - 3. Mar Mac 100124 - Weighted Average GB Permeation

MarMac Coverall 100124

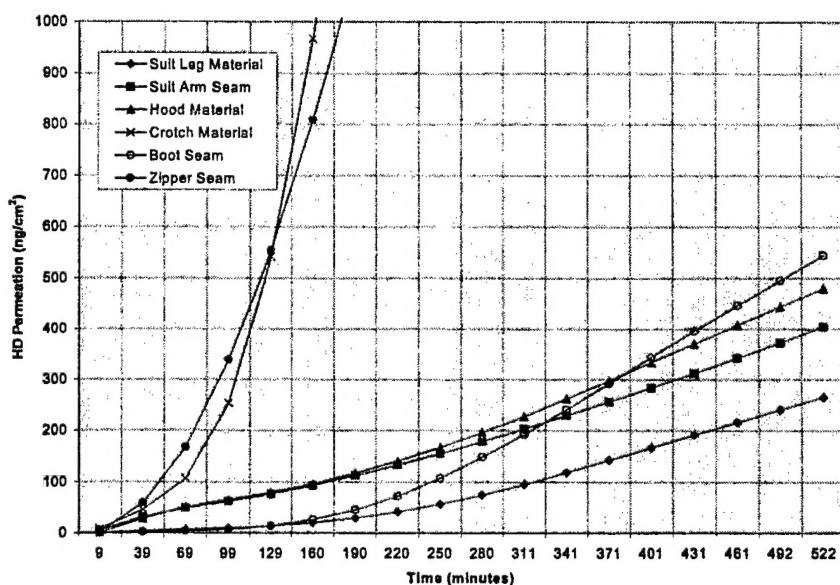


Figure E - 4. Mar Mac 100124 - HD Permeation By Sampling Area

MarMac Coverall 100124

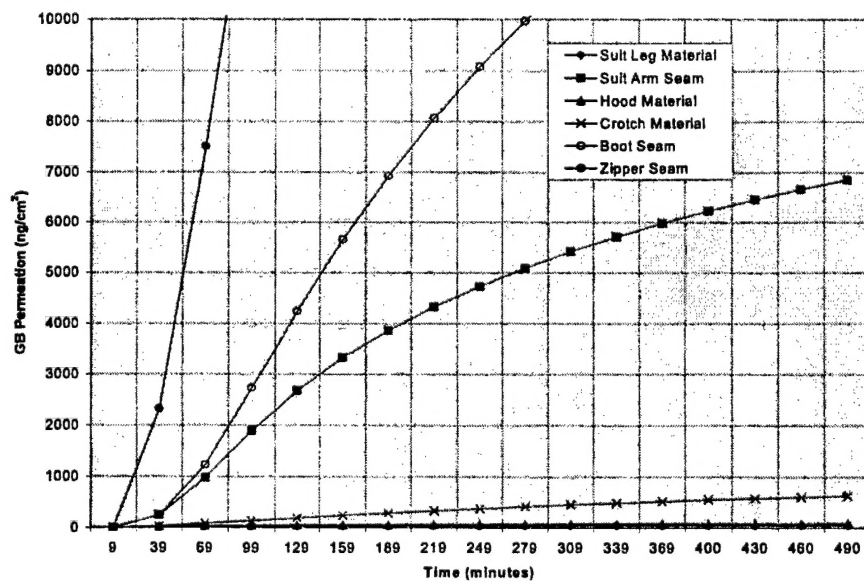


Figure E - 5. Mar Mac 100124 - GB Permeation By Sampling Area

Table E - 3. Mar Mac 100124 - System Test (Aerosol Simulant) Results

| PF | Visor Region and Upper Arm, Combined | | | | | |
|---------------|--------------------------------------|--------------------------|-------------------------------|-----------------------|--------------------------|-------------------------------|
| | Pre-Operational Exercises | | | Operational Exercises | | |
| | Frequency | Cumulative Rate, Percent | Cumulative Pass Rate, Percent | Frequency | Cumulative Rate, Percent | Cumulative Pass Rate, Percent |
| 0 | 0 | .00 | 100.00 | 0 | .00 | 100.00 |
| 2 | 13 | 54.17 | 45.83 | 14 | 58.33 | 41.67 |
| 5 | 10 | 95.83 | 4.17 | 9 | 95.83 | 4.17 |
| 10 | 1 | 100.00 | .00 | 1 | 100.00 | .00 |
| 50 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 100 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 150 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 500 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 1000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 1667 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 2000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 5000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 6667 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 10000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 20000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 50000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| 100000 | 0 | 100.00 | .00 | 0 | 100.00 | .00 |
| No. of Trials | 24 | | | 24 | | |

Table E - 4. Mar Mac 100124 - Overall Test Results

| Physiologically-derived breakthrough time (minutes) | | Aerosol PF Pass Rate (%) at PF Equal to: | | | Exercise Phase |
|---|----------|--|---|----|-----------------|
| Incapacitation | Erythema | | | | |
| GB | HD | 2 | 5 | 10 | |
| 152 | 185 | 46 | 4 | 0 | Pre-Operational |
| | | 42 | 4 | 0 | Operational |

Appendix F

Overall Test Results

Summary of HD Permeation Results

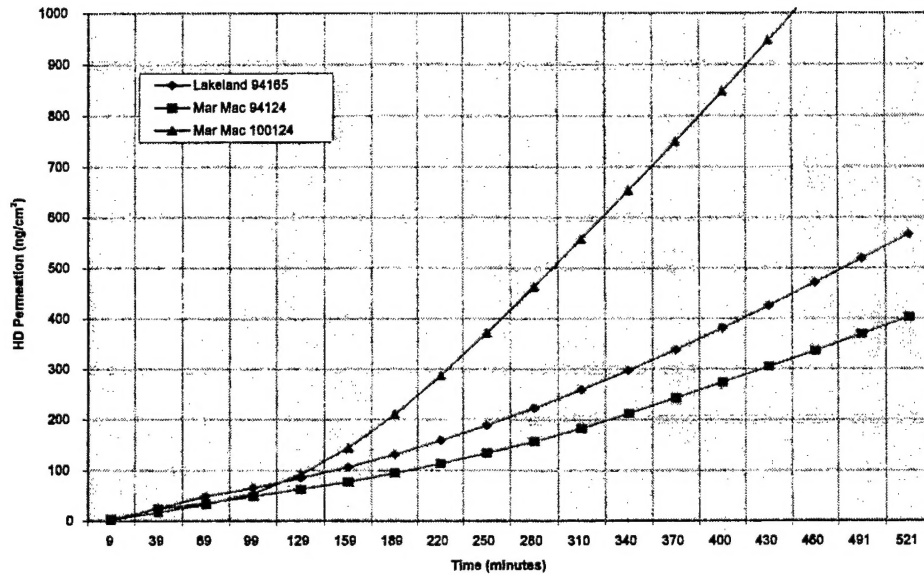


Figure F - 1. Weighted Average HD Permeation

Summary of GB Permeation Results

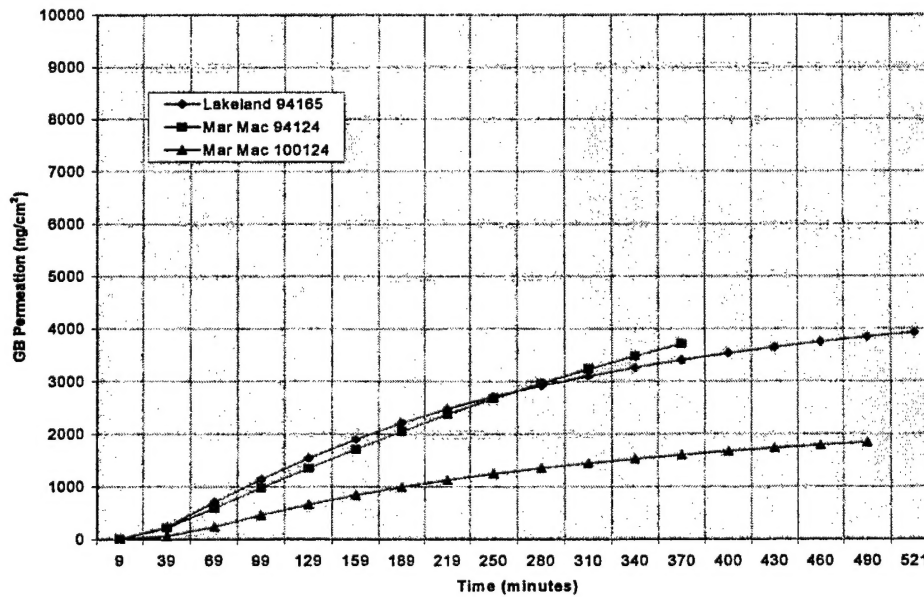


Figure F - 2. Weighted Average GB Permeation

Table F - 1. Summary of Overall Results for all Level B Suits

| Test Item | Physiologically-derived breakthrough time (minutes) | | Aerosol PF Pass Rate (%) at PF Equal to: | | | Exercise Phase |
|--------------------------------|---|----------|--|----|----|-----------------|
| | Incapacitation | Erythema | | | | |
| | GB | HD | 2 | 5 | 10 | |
| Lakeland Coverall, Style 94165 | 76 | 260 | 46 | 8 | 0 | Pre-Operational |
| | | | 46 | 8 | 0 | Operational |
| Mar Mac Coverall, Model 94124 | 86 | 329 | 50 | 25 | 0 | Pre-Operational |
| | | | 50 | 13 | 0 | Operational |
| Mar Mac Coverall, Model 100124 | 152 | 185 | 46 | 4 | 0 | Pre-Operational |
| | | | 42 | 4 | 0 | Operational |

The swatch testing indicates at least a moderate level of protection from permeation of GB and HD, but the aerosol test results suggest leakage through poorly sealed closures. This phenomenon has been noted for other suits, closures are a major issue. Aerosol testing evaluates penetration through openings and through materials that are permeable. Vapor testing (swatch) can evaluate impermeable materials.